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| <p>(21) International Application Number: PCT/FI90/00284<br/>(22) International Filing Date: 23 November 1990 (23.11.90)<br/>(30) Priority data: 895614 23 November 1989 (23.11.89) FI<br/>(71) Applicant (for all designated States except US): KEMIRA OY [FI/FI]; PL 44, SF-02271 Espoo (FI).<br/>(72) Inventors; and<br/>(75) Inventors/Applicants (for US only) : FRANCK, Marianne [FI/FI]; Pietarinkatu 2 C 27, SF-00140 Helsinki (FI). KURKELA, Sirpa [FI/FI]; Pengerkatu 21 A 39, SF-00500 Helsinki (FI).<br/>(74) Agent: BERGGREN OY AB; P.O. Box 16, SF-00101 Helsinki (FI).</p> |           | <p>(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent), SU, US.<br/><br/>Published<br/>With international search report.<br/>In English translation (filed in Finnish).</p> |
| <p>(54) Title: DNA MOLECULES IMPROVING COLD-RESISTANCE<br/><br/>(57) Abstract<br/><br/>The present invention relates to a novel gene which was isolated from the plant <i>Arabidopsis thaliana</i> L. More particularly, the present invention relates to a DNA molecule which comprises a structural gene which encodes a cold hardening protein or a protein which has similar biological properties and is substantially homologous with the said protein, and the regulating region of the structural gene.</p>   |           |  |

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## DNA molecules improving cold-resistance

The present invention relates to a novel cryoprotective gene which has been isolated from the plant Arabidopsis thaliana L.

In spite of the large amount of biochemical and physiological data available on the cold resistance of plants, what really happens to a plant in cold is not yet fully understood. For example, it is not known why certain plants tolerate freezing and others do not, or what the primary reason for cold damage is. An ability to improve the cold resistance of plants would provide considerable advantages for agriculture in cold regions of the globe.

The cold resistance of a plant is not a constant state but develops when the plant is exposed to low non-freezing temperatures (= acclimation). Although a number of cold acclimation specific changes have been observed in mRNA and in polypeptide profiles, very little is known about the action of these cold inducible proteins or about the mechanisms regulating these changes. So far, acclimation specific genes have not been isolated.

The object of the present invention is thus to isolate a cold hardening gene which can be transferred by genetic engineering methods into some crop plant and be induced to produce a protein which will enhance the resistance of the plant to cold.

In order to obtain additional information regarding the genetic and molecular bases of the cold hardening process of plants, cold acclimation specific genes from Arabidopsis thaliana were investigated in connection with the present invention. It was observed that Arabidopsis is cold resistant, and that this cold resistance is associated with a number of changes at the level of gene expression.

The present invention relates to a novel gene which was isolated from the plant Arabidopsis thaliana L. More particularly, the present invention relates to a DNA molecule comprising a structural gene which codes for a cold hardening protein or for a protein which has similar biological properties and is substantially homologous to the said protein, and its regulating region which responds to a drop in temperature.

It was observed that the gene kin1 was induced in six hours at +4 °C and acted as long as the plant was kept in cold and became inactive in 12 h when the plant was transferred back to the control temperature. The gene is also inducible by water stress and salt stress and by abscisic acid (ABA). ABA is a plant hormone which functions as a mediator in various plant stress situations, and it has been shown also to contribute to the cold acclimation of plants. ABA (50 µM) has been observed to raise the induction level to as high a level as does cold.

A genomic library was constructed in EMBL3, and cold inducible genes were identified by differential hybridization. One gene, the one which was induced most clearly, was selected for further characterization. A genomic clone was used as a probe for finding the corresponding cDNA clone in the enriched library which had been constructed in the plasmid pUEX1. Both clones were sequenced, the transcription initiation site was determined by the primer extension method, and the polyadenylation site from the cDNA sequences. The nucleotide sequence of the genomic clone is shown in Figure 1. The assumed regulating region of the gene is underlined, starting from the base pair 720 and ending with the base pair 2132. After this base pair there begins the actual structural gene of the DNA molecule. The cDNA sequence and the corresponding amino acid sequence are shown underlined in Figure 2.

The longest open reading frame (ORF) of the cDNA sequence,

starting from the first ATG downstream from the transcription initiation site, encodes a protein of 65 amino acids having a predicted molecular mass of 6478 and an isoelectric point of 7.2. The amino acid sequence of the protein is shown in Figure 3. Hybrid selection experiments showed that the kin1 clone hybridizes to mRNA(s) which encode a polypeptide of similar size. The protein is rather hydrophilic, and it has a high amount of  $\alpha$ -helical structure. Its amino acid composition is rather unusual: 22.4 % Ala, 13.4 % Gly and 13.4 % Ser. The gene contains the 5' and 3' untranslatable regions of the 62 and 117 nucleotides, respectively, and two introns.

The invention is described below in greater detail.

1) Isolation of a cold-inducible gene from the genomic library of the plant Arabidopsis thaliana  
For the genomic library, the total DNA of the plant Arabidopsis thaliana was fragmented partially by means of SAU3a restriction enzyme, and fragments of 15-20 kb were isolated from agarose gel. The fragments were ligated to BamH1 enzyme restricted arms of the vector  $\lambda$ EMBL3, and the ligation mixture was packed in vitro inside the  $\lambda$  particles by a method known per se (Maniatis et al., Molecular cloning, a laboratory manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1982). The E. coli host was infected with  $\lambda$  particles, and the recombinant phases which contained the cold-inducible gene were identified by so-called differential hybridization (on the dish, the phages formed plaques from which the DNA was transferred, by the method of Maniatis et al., to the filters used in the hybridization). The probes used in the differential hybridization consisted of cDNA made from RNA isolated from the control plants. For further experiments, a recombinant was selected which yielded in the hybridization a signal with cold cDNA but not with control cDNA. The fragment containing the gene was transferred from the  $\lambda$  vector to the pUC18 vector, and the more precise location of the gene in the fragment was determined by

differential hybridization. The 4369 kb fragment was sequenced.

## 2) Preparation of cDNA

cDNA corresponding to the genomic clone was captured from a cDNA library prepared from the cold RNA. The synthesis of cDNA from messenger RNA and its cloning into the vector pUEX1 were carried out using Amersham kits (RPN 1256 and RPN 1282). The probe used in the hybridization was a genomic clone. The cDNA was sequenced (Figure 2).

## 3) Southern blot analysis of DNA

Southern blotting was carried out by the method of Maniatis et al. (1982). The results of the genomic Southern blot test and the sequence analysis of cross-hybridizing cDNA clones shows that the gene is present in two copies in the genome of Arabis.

## 4) Northern blot analysis of RNA

The cold-inducibility of the gene kin1 was demonstrated by Northern blotting. The northern blot analysis was carried out by the method of Maniatis et al. (1982). Northern blotting was used for analyzing the steady state levels of kin1 mRNA during acclimation. Total RNA was isolated from the control plants and from the plants kept at a low temperature, by using the method described in Jones et al., High level expression of introduced chimeric genes in regenerated transformed plants, EMBO J. 4, pp. 2411-2418. The total RNA was analyzed carefully by the method of Maniatis et al., 1982. The results are shown in Figure 4. The figure shows that at low temperatures the amount of RNA corresponding to the kin1 gene is approx. 15-20 times the amount that is present at the control temperature, +22 °C, which means that the gene is cold inducible.

kin1 mRNA was detectable 6 hours after the transfer to a low temperature, and the level remained high throughout the 7-day acclimation phase. It was observed that the induction was cold

specific, i.e. when the plants were transferred back to the control temperature, the amount of kin1 mRNA dropped in 12 hours.

5) Investigation of the induction properties of the cold gene  
a) Absciscic acid (ABA)

Since the adding of exogenous absciscic acid (ABA) induces cold resistance in a number of plant species which are cold resistant, and an increase of endogenous ABA levels has been observed during this time, an investigation was made as to whether the kin1 gene would respond to ABA. The experiment was carried out as in point 4 above, by Northern blot analysis. The probe used was kin1 cDNA. Figure 5 shows the results of the effect of ABA (10 mM and 100 mM) on the expression of the kin1 gene. It was observed that both the spraying of Arabidopsis with 100  $\mu$ M ABA and watering it with 10  $\mu$ M ABA caused kin1 induction. This was the first time that direct molecular evidence of the role of ABA in cold acclimation was observed.

b) Water stress

An investigation was made as to whether the gene kin1 is inducible by water stress. The lowering of the cell water potential is common to this stress. It has been demonstrated that the damage caused to spinach leaves by wilting is similar to the dehydration caused by freezing. It has also been thought that tolerance of freezing is due to avoidance or tolerance of the dehydration caused by freezing. The dehydration is caused by ice formed in the extracellular space "sucking" the water out from inside the cell. It has also been noted that cold resistance can be induced in plants by mere desiccation stress, without exposure to low temperatures. When plants were exposed to desiccation of different degrees, it was observed that wilting really did induce the kin1 gene.

c) Salt stress

A high intercellular salt concentration results in water leav-

ing the cell, with dehydration resulting from it. An investigation was made whether the kin1 gene was inducible by salt stress (300 mM NaCl). The result of a Northern blot analysis shows that the kin1 gene is inducible also by salt stress (Figure 6).

6) Making of DNA constructs which are capable of action in plants, and their transfer into plants

The activity of the kin1 gene was investigated in cold-sensitive, non-acclimating tobacco plants~(Nicotiana tabacum SR1) and Arabidopsis, by using two different DNA constructs. The first construct (p35S-sense-kin1) contains the kin1 gene with the cDNA in the correct orientation (so-called sense), regulated by a strong, continuously acting cauliflower mosaic virus 35 S transcript regulating region (p35S; Fromm M. et al., 1985. Proc. Natl. Acad. Sci. USA, 82:5824-5828). In this manner the activity of the kin1 gene is in all parts of the plant independent of the temperature and the gene is also active in other plant species. In the other construct (p35S-antisense-kin1), the cDNA of the kin1 gene is in the wrong orientation (so-called antisense), regulated by p35S. The activity of the kin1 gene can be eliminated by transferring this construct into Arabidopsis, from which kin1 has been isolated. Thus it can be determined whether or not the kin1 gene is indispensable in the acclimation and cold resistance of Arabidopsis.

a) p35S-sense-kin1

The BamHI-BclI fragment of the pUEX1-cDNA clone was ligated to BamHI-digested plasmid pHTT203. The result was the plasmid pSKH100 (Figure 7), in which the kin1 cDNA was in the correct orientation under p35S regulation and which had the known neomycin phosphotransferase 2 nopaline synthase gene (pnos-npt2), used as the selectable marker, for fusion to the regulating region, and the known marginal areas of T-DNA which are needed for the transfer of DNA to a plant.



b) p35S-antisense-kin1

The NcoI fragment of the EX1-cDNA clone was ligated to BamHI digested plasmid pHTT200. The result was the plasmid pSKH107 (Figure 8), in which kin1 cDNA was in the wrong orientation under p35S regulation and which had the pnos-npt2 gene used as the selectable marker and the known marginal regions of T-DNA.

The p35S-sense-kin1 construct was transferred into tobacco plants and the p35S-antisense-kin1 construct was transferred to Arabidopsis plants by using a known Agrobacterium-mediated transfer method (Hernalsteens J.P. et al., 1980, Nature 287: 654-656; Valvetens D. et al., 1988, Proc. Natl. Acad. Sci. USA, 85:5536-5540).

7) Investigation of the action of the cold gene

a) In tobacco

Tobacco does not have the kin1 gene naturally. In transgenic plants into which the construct p35S-sense-kin1 has been transferred it was observed that the transferred recombinant gene is present and is detectable by the Northern blot analysis (Figure 9). In cold resistance tests, ion bleeding of tobacco leaf fragments is measured as a function of the temperature, by a known method (Sukumaran & Weiser, 1972, Hortscience 7:467-468). The plants are regarded as dead when a 50 % ion bleeding occurs. It was observed that the transgenic tobacco had a cold resistance approximately 1.2 degrees greater than had the control plant (Figure 10). This indicates that, when transferred into a cold-sensitive plant, the kin1 gene improves the cold resistance of the plant concerned.

b) In Arabidopsis

p35S-antisense-kin1 constructs were investigated in Arabidopsis. The cold resistance test on the transgenic plants (Figure 11) shows that the acclimation ability of p35S-antisense-kin1 plants is significantly lowered. These observations demonstrate that the kin1 gene affects the cold resistance of Arabidopsis.

and is indispensable for it.

8) Investigation of the regulating region

A genomic clone fragment Hind3-BsmI which contained regulation region was ligated to the glucuronidase gene (gusA; Jefferson R.A. et al., 1987, J. EMBO 6:3901-3907), and this fusion was transferred into a known vector which contained the selectable marker puos-npt2 and the marginal regions of T-DNA. The thus obtained construct pkin1-gusA in the plasmid pMEG3 (Figure 12) was transferred into tobacco plants by Agrobacter mediation.

The presence of the construct in a tobacco plant, and its activity, were investigated by determining the gus activity by a known method. Table 1 shows that pkin1 acts as the regulating region in tobacco, and its activity is higher at a low temperature.

Table 1

|                   | <u>A 415nm</u> |       |
|-------------------|----------------|-------|
|                   | +22 °C         | +4 °C |
| Control           | 0.01           | 0.01  |
| <u>pkin1-gusA</u> | 0.281          | 0.830 |

Claims

1. A DNA molecule, **characterized** in that it comprises a structural gene which encodes a cold hardening protein, and the regulating region of the gene.
2. A DNA molecule according to Claim 1, **characterized** in that the structural gene encodes a cold hardening protein isolated from the plant Arabidopsis thaliana L., or a protein which has similar properties and is substantially homologous with the said protein.
3. A DNA molecule according to Claim 1 or 2, **characterized** in that it is derived from Arabidopsis thaliana L.
4. A DNA molecule according to any of the above claims, **characterized** in that it has the base sequence shown in Figure 1, or part thereof.
5. A DNA molecule according to any of the above claims, **characterized** in that its structural gene has a base sequence which corresponds to the bases 2136-3100, or a part thereof, in Figure 1.
6. A DNA molecule according to Claim 1, 3 or 4, **characterized** in that its regulating region has a base sequence which corresponds to the bases 720-2132, or a part thereof, in Figure 1.
7. A DNA molecule according to any of the above claims, **characterized** in that its structural gene encodes a protein the amino acid sequence of which is depicted in Figure 3, or a protein of equivalent biological activity, having substantially the amino acid sequence depicted in Figure 3.
8. A DNA molecule according to Claim 5 or 6, **characterized** in that additional bases are ligated to the 5' and 3' ends of

the said base sequence.

9. A cDNA molecule, **characterized** in that it has the base sequence depicted underlined in Figure 2.

10. A crop plant or decorative plant, **characterized** in that a DNA molecule according to any of Claims 1-8 has been incorporated into it by genetic engineering methods.

11. A crop plant or decorative plant, **characterized** in that a cDNA molecule according to Claim 9 has been incorporated into it by genetic engineering methods.

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1 CCTGCACCTC GACTCTAGAG GATCCCCGGG TACCGAGCTC GAATTCGGAT 50  
 51 GATCCAAATG TTGAATATAA TGGATCAAGT ATCTATTATT ATGATCATT 100  
 101 TCATGATTTT AGTGTATTAA GCTAATTGCT TGCATTGA CTTTAAATCT 150  
 151 CATGACACCT TTGGTTTTTC ACATAGTTGA AATCTAGCTT AACCTCATAG 200  
 201 TTAACAAGGT CATAATATTT CGCCGAGGCA TAATAATCGA AAGAGTCAAA 250  
 251 GAAAGCGAGA GACGCACGAT AGAAAAAAAA AACTAGATAT ATTAAAAAAAA 300  
 301 TTTTTTTTTT TTTTAGATAT ATTAATTGA CTAAACGGCT ACGCTTTGTG 350  
 351 CCCAGTCTTC GTAGAGAATC GCTACGTTTT TATTGTAACC GAAACAAGAC 400  
 401 AAGAAACGTG TTTTCGATTG TGTTTGTGTA TCCGATAAA CTATTATATT 450  
 451 TTTGTAATTT GATTTAGTTC AAGAAATTGT TGTGGCCTAT CGGCTATCAA 500  
 501 CATGCTTTTT GTAAGAGAGA ACTTGTAATT TCTGTCTATG ATTCCTTCG 550  
 551 TTTCTTTTT CTCTCTCAA GTCATTTATT TAAAGAACA CATTACGTGT 600  
 601 GTATAATTGT ATAATTTTT CTATTTCTTA CTATACTTAG AGAATTACAT 650  
 651 GTTATAACAA ATGATCTTTG ATCAAAGAA AAACAACAAC AAATGATCAA 700  
 701 GAATTGCTTT CTTTTTTTTA TATGTTGCAA AATGAATAGA CGAGCCAAAC 750  
 751 TTATACTCAA ATATTGTTTT ATCTATTTTT AAGAAATATT CTTTATGCGA 800  
 801 GAGAGCAAAC TCCCCAAACG ATGTTAAATG GATCACAACA CATAAGTCGA 850  
 851 TCCGAATAGT TGAAGTTTT TAAAAAGGCA GTCCTATAA TTGTATTAA 900  
 901 CACACTAAAT CCTCCACACA CACAAAAGGA AATCAGTAA ACGAGACCTT 950  
 951 TACATGAAAC AATCAAACCA GTTTGATTTT ATCCGATTTT GCTAATGAGA 1000

FIG. 1

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1001 TGAGTTCTGT ATATTGTTAT AATGGATATA GGAGAACTAA CTAAAATAAA 1050  
1051 AAACGCAAAG AAAACTTTAT ACAGTACATA TTCTTATGGT CTTACCAATT 1100  
1101 ATCAACGATG TGTTGGTTAT GTACACAAGG TAAAATACAT CGATTCATAT 1150  
1151 TATGCATAAT ATAATGGGAA AATAAGAAT AAAACTACAT TTTGGTAACT 1200  
1201 TGAATTCAAC CATGAACTGT TTGGATTGGC AAACATAAAC TCAAATAAAA 1250  
1251 TATCTAGGTA TAATTGTGGT TCATACAAGA ATTACTTCAT ACTGTTGGGC 1300  
1301 CAAAGGGTAC GTATCCTTCC CCGCACCTCC AAACCATGGG CTTACTACTG 1350  
1351 ATCCGACATC AAAACCGTGT TAGTTGCAAC CAACGAATGA TAAGTCAATA 1400  
1401 AGATTCAACT TGTCAACAAA TATACAGCTT ATATGACATG TCTGGCTCCA 1450  
1451 AACTGAATTT TAGTAGAAAG TTACTAATTC ATAAAATTAA TTTATATACA 1500  
1501 ATTTTTCAAT TTTTATTTA TAAATTAAAG AAAAAACAT GAAAAATACG 1550  
1551 GGAGGTTTCGG CAAACACAAC ATTTAACTTG CCAAACGTAT CATCTAACTT 1600  
1601 TCCCACCTTA TACAAGGAAC CATTTTTTCA ATAATAAAGT TTTTTTTTTT 1650  
1651 TTTGTCTTC GCAAATAAGA GCACGAAATG TTTGCCAAAC GCATATGCAA 1700  
1701 CAAACCCACG TTACATAATT CTGTTTACAG CCATAGAGCA AGCTATATTG 1750  
1751 TTAAAGACCT AAAAAAATC TTTACTATAA CATATAGAGG CTTGAGATA 1800  
1801 TTTCGAAAGA CTCAACTTAT ATATAAATAA ACTCAAAAAG AAAACACGGA 1850  
1851 GGCGAGAGGA TCATACTCTC ACACAGAAAG AGTCACATTA TTATATCCTC 1900  
1901 TAAAAAACCA AACTAAAACG ACACGTGAAG TCTTGATCAG CCGATAAATA 1950  
1951 GCTACCGACA TAAGGCAAAA CTGATCGTAC CATCAAATGT AATCCACGTG 2000  
2001 GTTTtagatt ACTCGTGGCA CCACACTCCC TTAGCCTAT AAATATAAAC 2050

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2051 CATTAAGCCC ACATCTCTTC TCATCATCAC TAACCAAAAC ACACTTCAAA 2100  
2101 AACGATTTTA CAAGAAAAAA ATATCTGAAA AAATGTCAGA GACCAACAAG 2150  
2151 AATGCCTTCC AAGCCGGTCA GACCGCTGGC AAAGCTGAGG TACTACTCTT 2200  
2201 TCTCTCTTTG ACAGAACTCT TAAACTGGAA AAATTGTTGA AGCTATAACT 2250  
2251 CTTTGAAAAC AGTTGAAACT TGATCATTAC TAGAAATTTC AGTTACTTGT 2300  
2301 TTAATTTAGT TTGTCGTAAT TATGTAATTG ATGATTTTAT GGTTACAATG 2350  
2351 GTTGTCATGT AGGAGAAGAG CAATGTTCTG CTGGACAAGG CCAAGGATGC 2400  
2401 TGCAGCTGGT GCTGGAGCTG GAGCACAACA GGTAACAAT CCATACACAG 2450  
2451 ACACATAACA TATAATATGT AACGAAATAA ACGTCTTTGT AAGCTTACAT 2500  
2501 GTACGCAGAT TTCTGATATG GTTATGTATA TGTTATAGGC GGGAAAGAGT 2550  
2551 GTATCGGATG CGGCAGCGGG AGGTGTTAAC TTCGTGAAGG ACAAGACCGG 2600  
2601 CCTGAACAAG TAGAGATTCG GGTCAAATTT GGGAGTTATA ATTTCCCTTT 2650  
2651 TCTAATTAAC TGTGGGATT TTCAAATAAA CGATCTTTGA TCAAGAATTG 2700  
2701 CATTATATAT ATATATATAA AAATATATTG CAAAATTATT AGACGAGCCA 2750  
2751 AACTTATATT CAAATAATGT TTTATCTATT TTAAAAATA TTCTTTATGC 2800  
2801 GAAAGATCAA ACTCCCCAAA CGATGTATAA TGGATCACGA TACATAAGTC 2850  
2851 GATCCGAATT GTTGAAGTTT TCTAAAAATG CAGTCCTTAT AATTGTATTA 2900  
2901 AACACACTAA ATCTTCCAAA CACACAGAAG GAAATCACGT AAACGAGACC 2950  
2951 TTTACATGAA ACTATCAAAC CAGTTTGAGT TTATCCGATT TTGCTAATGA 3000  
3001 GACGAGTTCT ATATATTGTT ATAATGGATA TAGGAGAACT AACTAAAAAA 3050  
3051 AAACGCAAAG AAAACTTTAT ACATATTCTT ATGGTCTTAC CAATAATCAA 3100

|      |   |      |
|------|---|------|
| 2001 | GT TTTAGATT ACTCGTGGCA CCACACTCCC TTTAGCCTAT AAATATAAAC       | 2050 |
| 2051 | CATTAAGCCC ACATCTCTTC <u>TCATCATCAC TAACCAAAAC ACACTTCAAA</u> | 2100 |
| 2101 | <u>AACGATTTTA CAAGAAATAA ATATCTGAAA AAATGTCAGA GACCAACAAG</u> | 2150 |
|      | MetSerG1 uThrAsnLys   |      |
| 2151 | <u>AATGCCTTCC AAGCCGGTCA GACCGCTGGC AAAGCTGAGG TACTACTCTT</u> | 2200 |
|      | AsnAlaPheG InAlaGlyG1 nThrAlaGly LysAlaG1                     |      |
| 2201 | TCTCTCTTTG ACAGAACTCT TAAACTGGAA AAATTGTTGA AGCTATAACT        | 2250 |
| 2251 | CTTTGAAAAC AGTTGAAACT TGATCATTAC TAGAAATTTT AGTTACTTGT        | 2300 |
| 2301 | TTAATTTAGT TTGTCGTAAT TATGTAATTG ATGATTTTAT GGTTACAATG        | 2350 |
| 2351 | GTTGTCATGT <u>AGGAGAAGAG CAATGTTCTG CTGGACAAGG CCAAGGATGC</u> | 2400 |
|      | uGluLysSe rAsnValLeu LeuAspLysA laLysAspAl                    |      |
| 2401 | <u>TGCAGCTGGT GCTGGAGCTG GAGCACACA GGTAACAAT CCATACACAG</u>   | 2450 |
|      | aAlaAlaGly AlaGlyAlaG lyAlaGlnG1                              |      |
| 2451 | ACACATAACA TATAATATGT AACGAAATAA ACGTCTTTGT AAGCTTACAT        | 2500 |
| 2501 | GTACGCAGAT TTCTGATATG GTTATGTATA TGTTATAGGC <u>GGGAAAGAGT</u> | 2550 |
|      | nAl aGlyLysSer  |      |
| 2551 | <u>GTATCGGATG CGGCAGCGGG AGGTGTTAAC TTCGTGAAGG ACAAGACCGG</u> | 2600 |
|      | ValSerAspA laAlaAlaG1 yGlyValAsn PheValLysA spLysThrG1        |      |
| 2601 | <u>CCTGACCAAG TAGAGATTGG GGTCAAATTT GGGAGTTATA ATTTCCCTTT</u> | 2650 |
|      | yLeuAsnLys TER  |      |
| 2651 | <u>TCTAATTAAC TGTTGGGATT TTCAAATAAA CGATCTTTGA TCAAGAATTG</u> | 2700 |
| 2701 | <u>CATTATATAT ATATAATAT ATTGCAAAATT</u> ATTAGACGA GCCAAACTTA  | 2750 |
| 2751 | TATTCAAATA ATGTTTTATC TATTTTAAAAA ATATTCTTT ATGCGAAAGA        | 2800 |

FIG. 2



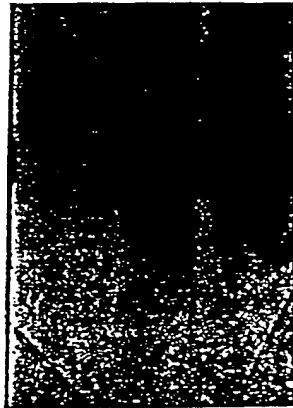
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Met Ser Glu Thr Asn Lys Asn Ala Phe Gln Ala Gly Gln Thr Ala Gly Lys 17  
Ala Glu Glu Lys Ser Asn Val Leu Leu Asp Lys Ala Lys Asp Ala Ala Ala 34  
Gly Ala Gly Ala Gly Ala Gln Gln Ala Gly Lys Ser Val Ser Asp Ala Ala 51  
Ala Gly Gly Val Asn Phe Val Lys Asp Lys Thr Gly Leu Asn Lys TER

FIG. 3

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A B C



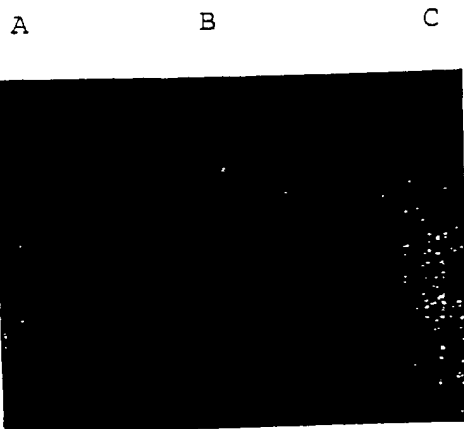
A = +22°C

B = +4°C, 1 day

C = +4°C, 2 day

FIG. 4

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A = +22°C

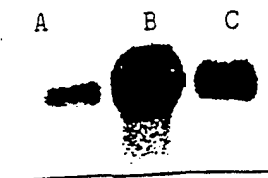
B = +4°C, 1 day

C = 10 mM ABA, "

D = 100 mM ABA, "

FIG. 5

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A= +22°C

B= +4°C, 1 day

C= +22°C, 300 mM NaCl, 1 day

FIG. 6

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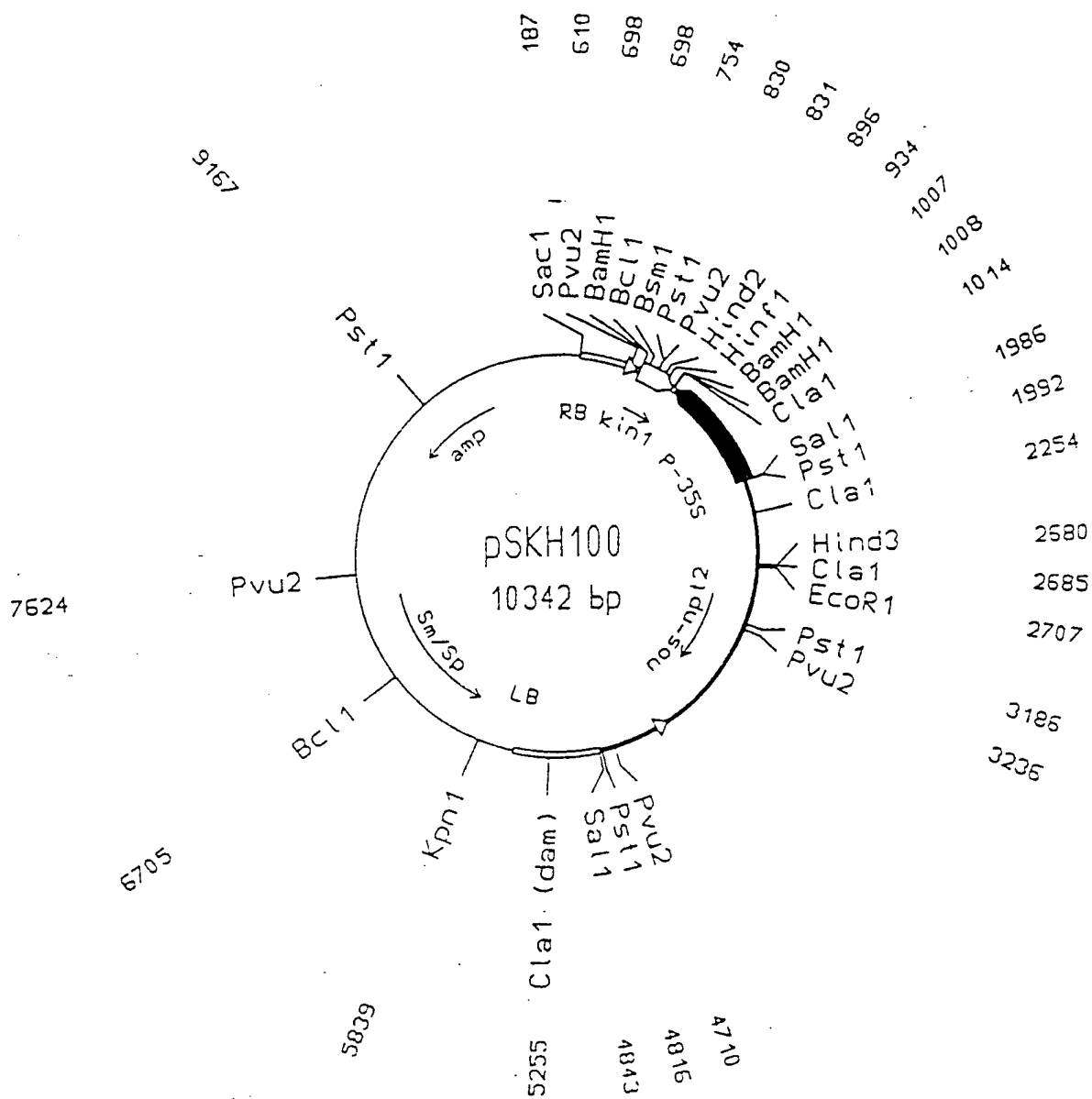


FIG. 7

|      |      |
|------|------|
| 187  | 187  |
| 610  | 610  |
| 698  | 698  |
| 698  | 698  |
| 739  | 739  |
| 812  | 812  |
| 850  | 850  |
| 915  | 915  |
| 916  | 916  |
| 992  | 992  |
| 1048 | 1048 |
| 1054 | 1054 |

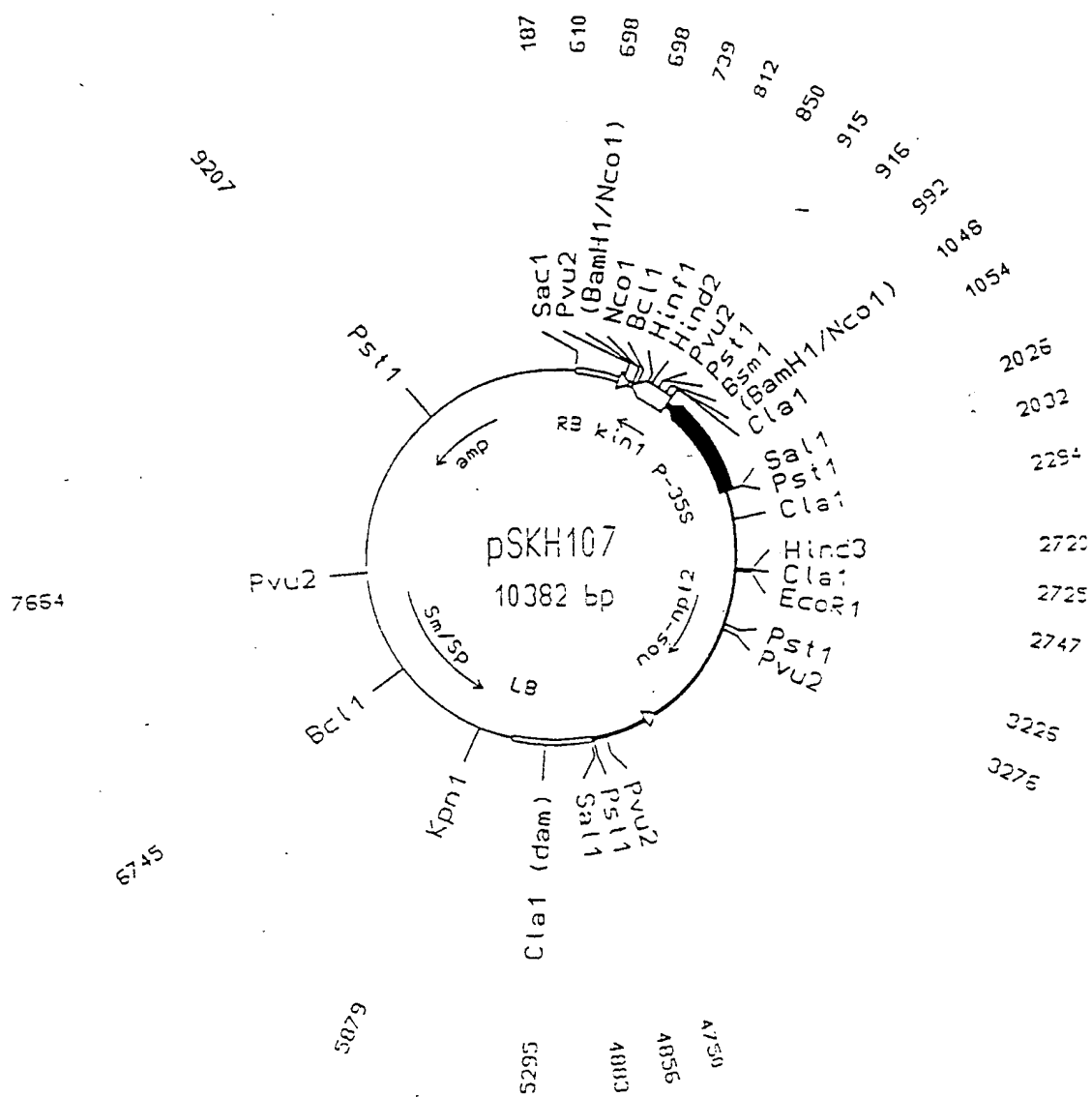


FIG. 8

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A B C

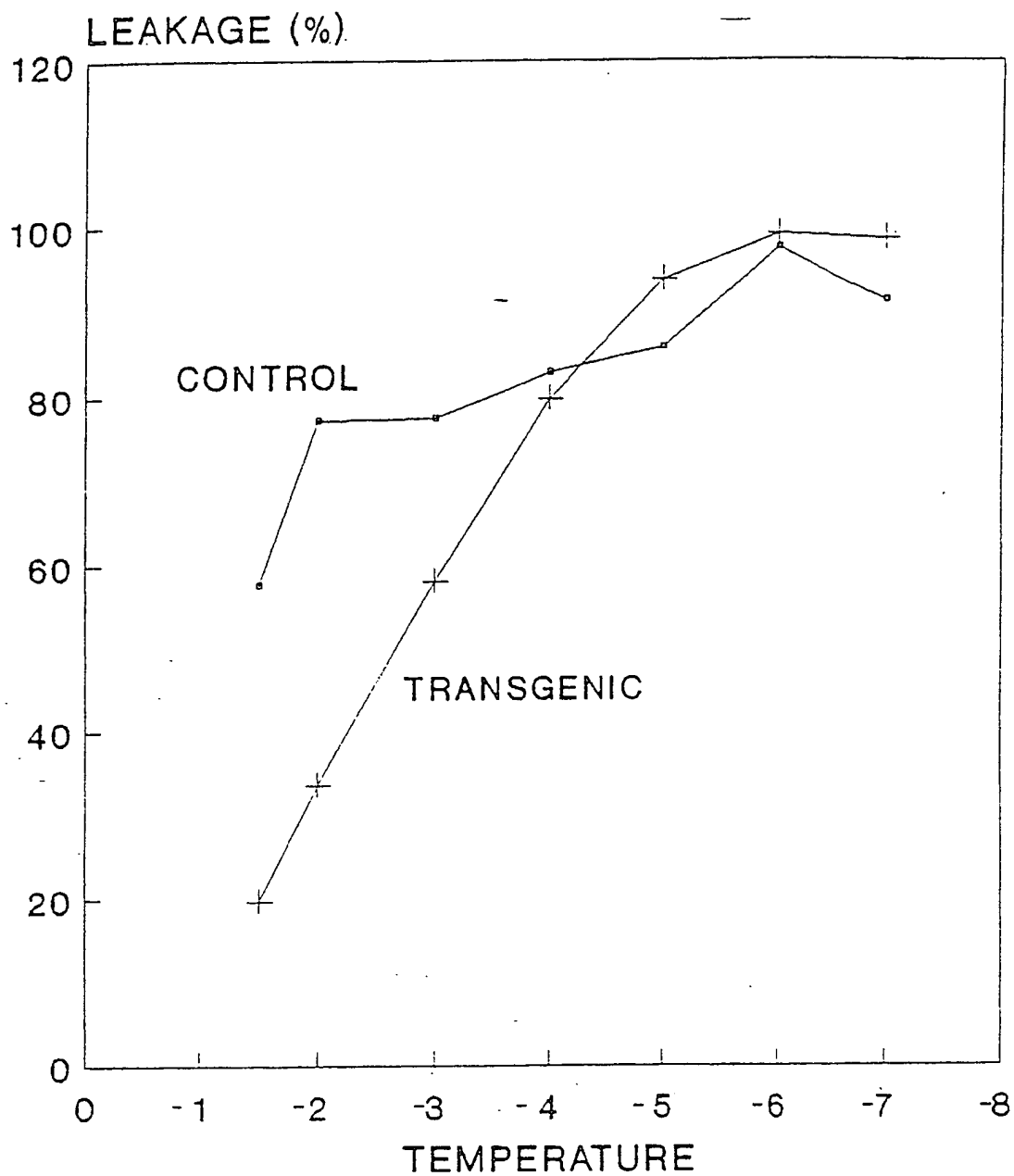


A= non-transformed tobacco  
B= acclimated Arabidopsis RNA  
C= tobacco transformed with p35S-sense-kin1

FIG. 9

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## ION LEAKAGE IN NICOTIANA



CONTROL= wild type Nicotiana  
TRANSGENIC= Nicotiana transformed with  
p35S-kin1

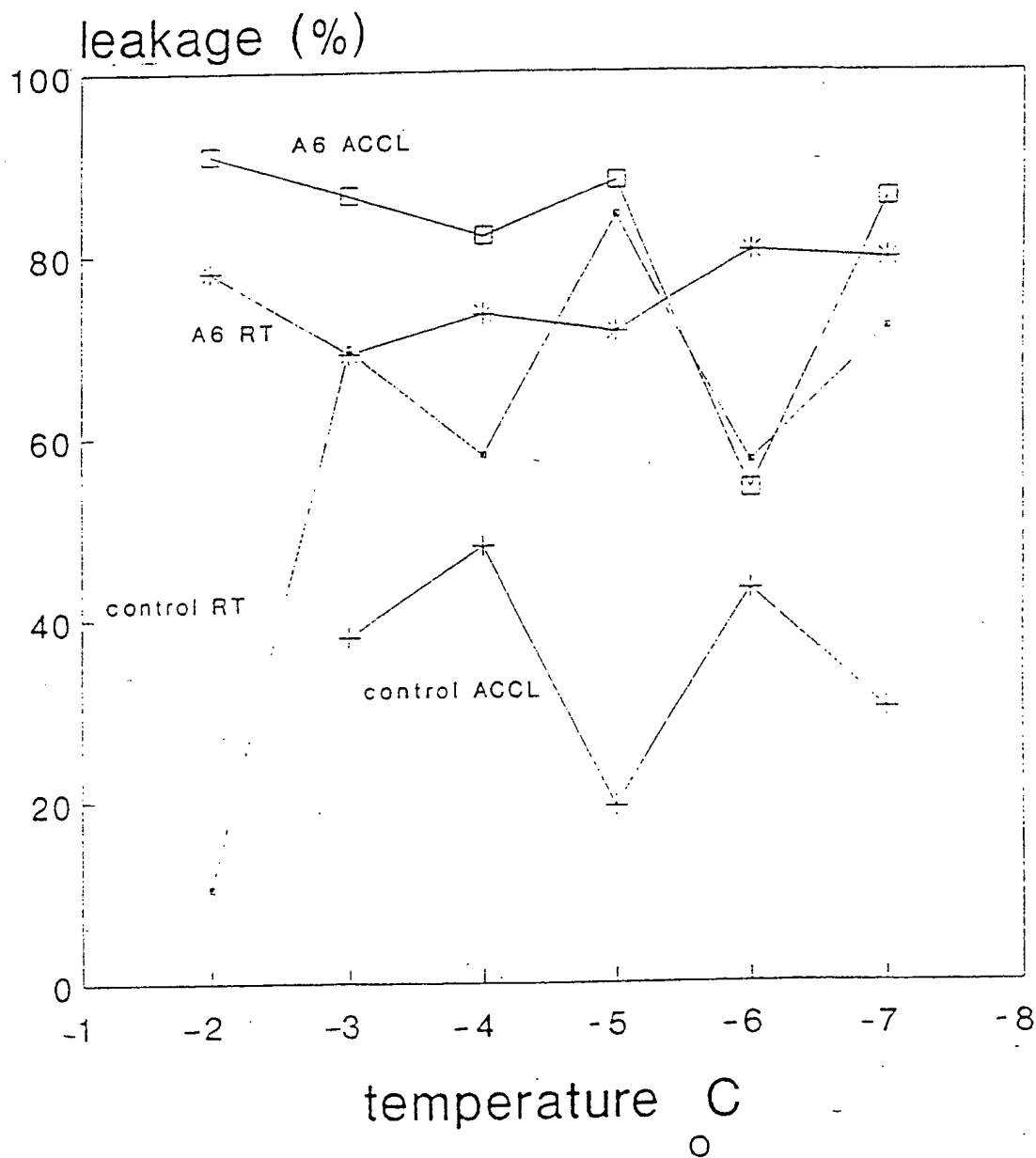
FIG. 10



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# ION LEAKAGE IN ARABIDOPSIS

control and antisense



RT= +20 C ACCL= acclimatized +4 C  
control = non-transformed  
A6=transformed with p35S-antisense-kin1

FIG. 11

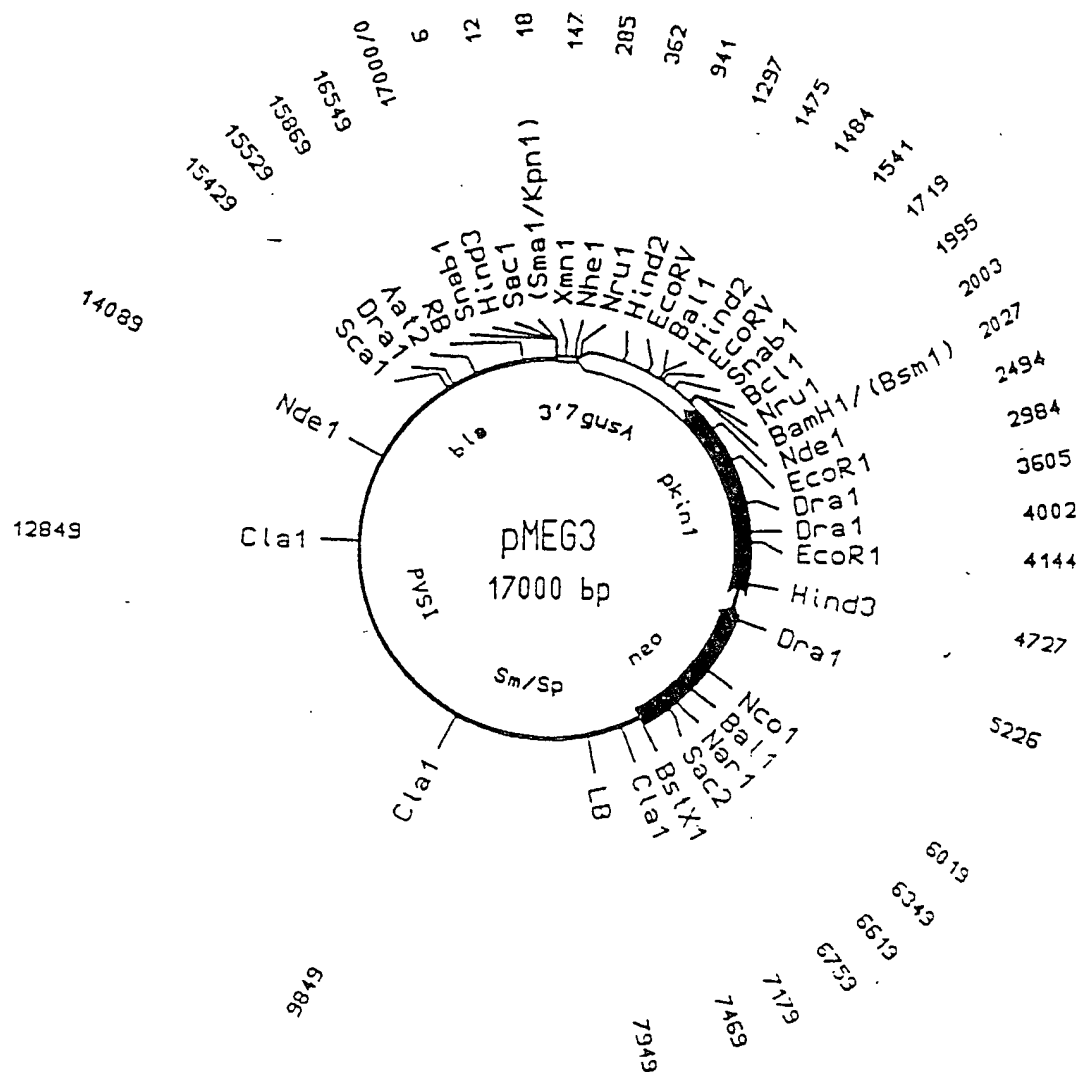
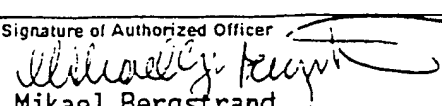


FIG. 12

# INTERNATIONAL SEARCH REPORT

International Application No PCT/FI 90/00284

|  |  |                                     |
|--|--|-------------------------------------|
| <b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>  |  |                                     |
| According to International Patent Classification (IPC) or to both National Classification and IPC<br>IPC5: A 2 N 15/29; C 12 N 15/82, A 01 H 4/00  |  |                                     |
| <b>II. FIELDS SEARCHED</b>   |  |                                     |
| Minimum Documentation Searched <sup>7</sup>  |  |                                     |
| Classification System  | Classification Symbols   |                                     |
| IPC5   | C 12 N; A 01 H   |                                     |
| Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched <sup>8</sup>   |  |                                     |
| SE,DK,FI,NO classes as above   |  |                                     |
| <b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>  |  |                                     |
| Category *   | Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>   | Relevant to Claim No. <sup>13</sup> |
| A  | EP, A2, 0338266 (THE GENERAL HOSPITAL CORPORATION)<br>25 October 1989,<br>see the whole document<br>--   | 1-11                                |
| P,X  | Plant Molecular Biology, Vol. 15, 1990 Sirpa Kurkela et al.: "Cloning and characterization of a cold- and ABA-inducible Arabidopsis gene", see page 137 - page 144 the whole article<br>-- | 1-11                                |
| X  | Plant Physiol, Vol. 87, 1988 Sarah J. Gilmour et al.: "Cold Acclimation in Arabidopsis thaliana", see page 745 - page 750 whole article<br>--  | 1-3,10-11                           |
| <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </div> </div> |  |                                     |
| <b>IV. CERTIFICATION</b>   |  |                                     |
| Date of the Actual Completion of the International Search<br><br>22nd February 1991  | Date of Mailing of this International Search Report<br><br>1991-02-27  |                                     |
| International Searching Authority<br><br>SWEDISH PATENT OFFICE   | Signature of Authorized Officer<br><br>Mikael Bergstrand   |                                     |

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) |  |                      |
|--|--|----------------------|
| Category *   | Citation of Document, with indication, where appropriate, of the relevant passages   | Relevant to Claim No |
| X  | Supplement to Plant Physiology, Vol. 89, No. 4,<br>1989 Gilmour et al.: "Scientific program for<br>the Annual Meeting of the American Society of<br>Plant Physiologists",<br>abstract no. 802<br>--                | 1-3,10-<br>11        |
| X  | Hajela et al. "Journal of Cellular Biochemistry,<br>Supplement 13 D", 1989, Alan R. Liss, Inc.,<br>abstract no. 417<br>--  | 1-3,10-<br>11        |
| X  | J. Plant Physiol., Vol. 135, 1989 Adrian J. Cutler<br>et al.: "Winter Flounder Antifreeze Protein<br>Improves the Cold Hardiness of Plant<br>Tissues", see page 351 - page 354<br>the whole article<br>--<br>----- | 1,10-<br>11          |

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.PCT/FI 90/00284

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the Swedish Patent Office EDP file on 91-01-31  
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)      | Publication<br>date  |
|---|---------------------|---------------------------------|----------------------|
| EP-A2- 0338266                            | 89-10-25            | AU-D- 3346489<br>WO-A- 89/09219 | 89-10-16<br>89-10-05 |

